DOCUMENT RESUME

ED 064 375 TM 001 620

AUTHOR Bashook, Philip G.
TITLE A Methodology for Analysing and Evaluating Teaching Strategies in University Science Teaching.
NOTE 45p.

EDRS PRICE MF-$0.65 HC-$3.29
DESCRIPTORS Classification; Concept Teaching; Conceptual Schemes; *Evaluation Techniques; *Research Methodology; *Science Instruction; *Teaching Techniques; Theories; *Universities
IDENTIFIERS *Smith (B O)

ABSTRACT

An approach to analyzing and evaluating strategies for teaching science concepts at the first-year university level based on B. O. Smith and co-workers' conceptual framework of teaching was explored. The study assumed that teaching is a type of goal-directed activity. Specifically, this paper offers a description of a methodology for analyzing and evaluating concept teaching in university science courses using Smith and coworkers' framework and explores the usefulness of the methodology for teaching. The methodological bridge has four phases: (1) identify aspects of Smith and co-workers' conceptual framework which appear useful for analyzing the actual teaching of science concepts; (2) characterize a record of actual teaching strategies employed; (3) Analyze and evaluate the results of Phase II; and (4) Suggest specific problems arising from this study having general application to university science teaching which need further investigation. A general conclusion of the study is that the theoretical framework used appears to be potentially useful for analyzing and evaluating certain aspects of classroom teaching. The venture and move categorizations of the framework proved tractable for analyzing actual teaching strategies performed in a lecture-type teaching situation. Other useful parts of the methodology include: (1) classifying and organizing the information introduced by the various moves of a venture, (2) tabulations of the information introduced about a concept, and (3) analyzing conceptual ventures. (CK)

7.3

A METHODOLOGY FOR ANALYSING AND EVALUATING TEACHING STRATEGIES IN UNIVERSITY SCIENCE TEACHING[1]

Philip G. Bashook
University of Illinois
College of Medicine[2]

Introduction

The study explored an approach to analysing and evaluating strategies for teaching science concepts at the first-year university level based on B.O. Smith and co-workers' conceptual framework of teaching. As such, the study represents an attempt to bridge the gap between a recently developed theoretical view of teaching and practical problems of classroom teaching.

Smith et al (1962, 1967), followed by Coombs (1969), studied teaching strategies with respect to various subject matter goals achieved and the logical operations used to achieve them. The authors identified a number of teaching strategies which can lead, logically, to different teaching goals. The work of these researchers make it possible to assess, on logical grounds, the goodness-of-fit of an actual teaching strategy to an idealized teaching strategy as indicated by a teaching goal. Included in their study are procedures and criteria for observing and analysing teaching behavior in the classroom.

A basic assumption made in the study was that teaching is a type of goal-directed activity. The major goal of science teaching was taken to be the acquisition of scientific paradigms. According to T.S. Kuhn (a philosopher-historian of science), scientific paradigms constitute what a "scientific community thinks it knows." Many paradigms center on concepts while others focus on methods of observation and instrumentation (Kuhn, 1962). For example, in physics one teaches the concept of "electric

[1]Paper presented at the Annual Convention of the American Education Research Association, April 3-7, 1972 in Chicago, Ill.
[2]The paper is based on a doctoral dissertation submitted at the University of British Columbia, Vancouver, Canada, 1971.

charge" as a theoretical paradigm basic to solving scientific puzzles having to do with the phenomenon of electromagnetic induction. Since science concepts are inextricably bound to scientific paradigms, the teaching of science concepts is seen as an essential aspect of science teaching strategies. Moreover, teaching strategies used to teach science concepts are rarely, if ever, firmly based on systematized knowledge of teaching.

By analysing the logical verbal operations in teaching strategies actually employed to teach a concept and assessing the results in terms of the intended objective (i.e., explicating a particular concept), one may be able to suggest on logical grounds whether the strategy employed could lead to the intended objective. Having identified successful and unsuccessful teaching strategies on this basis, for particular objectives, it should be possible to speculate on preferred science teaching strategies for particular teaching objectives, and to offer suggestions for subsequent empirical investigations.

Specifically, this paper offers a description of a methodology for analysing and evaluating concept teaching in university science courses using Smith and co-workers' (1967) framework, including revisions (i.e., Coombs, 19( )) and explores the usefulness of the methodology for teaching.

Data Used to Illustrate The Methodology

Examples of university science teaching have been selected to demonstrate the methodology. The lecture segment of an introductory university physics course (Physics 110, University of British Columbia, 1969-1970) forms the data source for teaching strategies and goals. The course was designed for a heterogeneous population of first year university students not planning to major in physics (approximately 650 students in all; Physics Education Evaluation Project, Interim Report, January 1970, p.8). During the course students attended separate lecture sections but retained a common laboratory experience. Data for this study was obtained from two lecture sections, both taught by the same instructor.

The instructor willingly permitted and encouraged the collection of the data used in this study. For example: he permitted unobtrusive audio-taping of his lectures; he conscientiously completed a questionnaire describing his teaching goal for each lecture; and he actively participated in many discussions with the writer concerning his (the instructor's) teaching goals in the physics course.

Transcripts of a selected set of lectures from the instructor's course form the data source for actual teaching strategies. The transcripts have been made from audio-tapes which were obtained by recording off the public address system during lectures. Additional written information presented in the lecture on overhead transparencies was obtained but was not useful for this study.

Teaching goals for the teaching strategies were obtained from two sources. The instructor of the physics course prepared a course rationale in which he gave his broad goals for the course and some justification for these goals (Physics Education Evaluation Project, Interim Report, January 1970, pp. 10-17). The course rationale serves as a means to focus on the instructor's broad teaching goals. The instructor also completed, prior to each lecture, an analysis of the objectives for the lecture, the importance of these objectives for the lecture, the importance of these objectives to the course and the lecture, and other information about what he intended to do in the lecture. Pre-lecture analyses form the data source to pinpoint specific content objectives for each lecture. Figure 1 is an example of a pre-lecture analysis questionnaire used in the study.

From the approximately one hundred and forty lectures presented in each of two sections of the introductory university physics course, eleven lectures were selected for the purposes of the present study. The lectures represent examples of teaching strategies for each of the eight months of the course excluding the first and last month. The lectures selected met three criteria: First, the instructor had indicated on the pre-lecture analysis questionnaire that he planned to teach a concept; second, a record (audiotape, etc.) of the actual teaching strategies in the lecture had been made; and third, the instructor indicated on the questionnaire the importance of the concept to the course--lectures containing concepts which were moderate to very important, as rated by the instructor, were selected. The lectures are the data used in illustrating the methodology.

Table 1 presents the concept terms taught (Column 1), month in which venture occurred (Column 20), importance of the

Figure 1

Lecture section A

Lecture date March 3rd, 1970

Number of [illegible] for this transaction

1 of 1

TRANSACTION: WAVE SUPERIMPOSE

PURPOSE: STATE IMPORTANT WAVE PROPERTY AND LIMITATIONS

APPROPRIATE TAXONOMY POSITION: 1.22 COGN. AFFECTIVE
(Cognitive domain, or if applicable Affective domain)

METHOD OF PRESENTATION: (please circle appropriate method(s))

Lecture
Film
Slides
Demonstration
Token demonstration
Other (specify)

IMPORTANCE: For each group of students how important is this purpose of this transaction? Please use a five point scale with 5 = very important, and 1 = unimportant. Use a questionmark (?) for not sure.

		all	1st	2nd	up pass	low pass
Cognitive	for "scientific literacy"	4				
	for reinforcing a concept	1				
	for technical purpose in course	3				
	for technical purpose in lecture	5				
Attitude	for physics in general					
	for this course					
	for this lecture					

EXPECTED STUDENT INTEREST: (please circle the appropriate level for each)

Students						
1st class	low 1	2	3	4	5	high
2nd class	1	2	3	4	5	
Upper Pass	1	2	3	4	5	
Lower pass	1	2	3	4	5	
Probable fail	1	2	3	4	5	

EXPECTED STUDENT PREPARATION:

Previous lecture(s): February 25th, 1970
(please indicate date)

Text material: --

Lab. Experience: [illegible] (For those who did [illegible])

Other (specify): [illegible] WAVES

EVIDENCE OF STUDENT UNDERSTANDING WILL BE OBTAINED: (circle appropriate)

Do not know | Attitude test | 1st midterm | Christmas exam
Not at all | Lab. reports | 2nd midterm | Final exam

TABLE 1. Data on Concept Ventures Selected For Study

Concept Name (1)	Month Venture Performed (2)	General Importance of Concept* (3)	Number of Moves in Venture (4)
Mass	October	5	5
Mass	October	5	17
Law in Physics	November	4	6
Electricity	November	2	10
Law in Physics	December	3	5
Law in Physics	January	4	5
Electric Field	January	5	9
Number of Field Lines	February	2	4
Feedback	March	5	6
Superposition of Waves	March	4	12
Nuclear Binding energy	March	3	7

*A composite score of what the instructor stated to be important in the lecture. Scale endpoints are:

5 = very important
1 = minor importance

See text for further information.

concept to the course (Column 30), and the number of moves in each conceptual venture (Column 4).

In the eleven ventures identified for the study, eight different concepts were taught. The eight concept terms are: "Mass", "Law in Physics", "Electricity", "Electric Field", "Number of Field Lines", "Feedback", "Wave Superposition", and "Nuclear Binding Energy." The concept termed "Law in Physics" was taught in three separate ventures; the remaining concepts were taught in a single venture.

Methodology

The methodological bridge has four phases:

Phase I <u>Identify</u> aspects of Smith and co-workers' (1962, 1967) conceptual framework which appear useful for analysing the actual teaching of science concepts in a first year university physics course.

Phase II <u>Characterize</u> a record of actual teaching strategies employed in teaching science concepts in a university science course.

- A. Categorize a conceptual venture into moves.
- B. Organize the information contained in the moves with respect to the functions they accomplish in teaching the concept.
- C. Display the organized information in summary form (Table 2).

Phase III <u>Analyse and evaluate</u> the results of Phase II with a view to devising teaching strategies for specific teaching goals based on logical teaching operations conforming to the teaching models developed by Smith and co-workers.

- A. Deduce rule-formulations for the concept seen as the "potential product" of the actual teaching strategy.
- B. Deduce an ideal set of rule-formulations that meet certain epistemic rules for teaching functions

as the "intended product" of an ideal teaching strategy for the same concept.

C. Match the "potential product" with the "intended product" for similarity of information and "rule-formulations" for the concept.

D. Devise teaching strategies specifically for the concept based upon results of the matching procedure.

Phase IV <u>Suggest</u> specific problems arising from this study having general application to university science teaching which need further investigation.

A. Difficulties in using the "conceptual venture" categorizations.

B. Problems in concept teaching.

C. Development of handbook of Teaching Strategies for Selected Science Concepts.

The unique contributions made in the methodological bridge are: a procedure in Phase II for organizing information about the concept presented as moves in a teaching activity; procedures in Phase III for analysing and evaluating from a logical viewpoint, actual teaching performed in a classroom; and the specific suggestions for further empirical studies (Phase IV). Each phase is discussed below with an illustration from concept teaching in a first-year university physics course.

Phase I: Identifying Aspects of Smith and Co-Workers' Theoretical Framework

The basic task of this phase is to make explicit the particular concepts, constructs, and classifications of the conceptual framework deemed useful for analysing the teaching of concepts. Aspects of Smith and co-workers' conceptual framework (Smith <u>et al</u>, 1962, 1967; Coombs, 1969) concerned with the means of instruction and logical operations involved in performing various teaching acts were identified and described. For a complete discussion of this information the reader is referred to Bashook, 1971, Chapter II.

If one assumes that an important goal of teaching a concept is the attainment of the concept by those being taught, then following the frameworks description of the term "concept" (see page 12) attaining a concept would mean having "rules for using the term which names the concept and rules governing one's behavior with respect to including or excluding things from the class designated by the term." (Coombs, 1969, p.1).

Coombs (1968) suggests three functions to be accomplished in teaching a concept for attainment. These are:

1. Make clear how the concept relates to a number of other concepts the student has (provide relational meaning);

2. Relate the concept to actual events, objects, actions, or situations in the students' experience (provide experimental reference);

3. Make clear the context within which the concept has application (provide content).

Coombs, 1969, p.1)

As a means of explaining teaching functions consider the following example. To teach the concept "gravitational mass" in a physics class the teacher could provide "relational meaning" by relating it to the concept "weight." Gravitational mass, unlike weight, is an unchanging property of a body. The weight of a body--the pull of gravity on it--changes, for example, when the object is moved from the earth to the moon. However, the gravitational mass of the object remains unchanged (PSSC, 1965, p.327).

The teacher might provide experimental reference for the concept by building upon the following:

> Gravitational mass is what you measure with a beam balance in equilibrium. Two masses that balance on earth will also balance anywhere else--in a rocket leaving the earth, on the planet Jupiter, or anywhere else in the universe.
>
> (PSSC, 1965, pp. 327-328)

A contextual definition for "gravitational mass" could be:

> It is appropriate to use the term gravitational mass in situations where it makes sense to talk about what is measured by a balance in equilibrium under gravitational forces and where motion is irrelevant.
>
> (PSSC, 1965, pp. 327-328)

Key concepts identified in the conceptual framework and used as part of this discussion are: "teaching strategies," "concepts", "ventures", "moves", and "epistemic rules". For reference, these concepts are described below.

The term teaching strategies has been taken to mean the control of the subject matter of instruction by the teacher in order to attain certain outcomes or objectives and to guard against others (Smith, et al, 1967, p.49).

The term concept is described as "a rule or set of rules governing the use of a term" and "determining what things do or do not belong in a given class" (Coombs, 1969, p.1). Implicit within this description of concept is a distinction between the name, term or phrase used, and the class or category of things to which the term is used to make reference (i.e., the "referent"; Smith, et al, 1967, p.58).

"A segment of discourse consisting of a set of utterances (verbal behavior of one person at one point in a class session) dealing with a single topic and having a single overarching content objective (central focus of discussion)" is referred to, generally, as a venture (Smith, et al, 1967, p.6). Eight different classes of ventures were identified by Smith and co-workers. Conceptual ventures have as their overarching content objectives "disclosing the conditions or criteria governing the use of a term" (Smith, et al, 1967, p.294).

A venture can be further analysed into units termed "moves" (Smith, et al, 1967, p.53). Move refers to the verbal activity which introduces one particular bit of information dealing with the venture objective. A teacher, a student, or a teacher and one or more students together may make a move (Coombs, 1969, p.14).

In the teaching of a particular concept (i.e., in a conceptual venture) a move should help make clear the meaning of the concepts. Smith and co-workers (1967, p.55) view the activities of making clear the meaning of a concept, which are described by the term moves, as logical operations aimed at attaining a specific teaching objective.

As a means of illustrating moves, consider the following scheme:

> Let a, b, c, constitute the conditions governing the use of the term d (biological misnomers), and the objects to which d is applicable be denoted by x, y, z.
>
> (Smith et al, 1967, p.55).

By offering instances of x, y, and z, the teacher and students could explicate the term d, "biological misnomers". The following three moves might serve this purpose.

Move for x

T: Can you name any other animals that we usually refer to as fish but that do not belong with the fish at all?

S: The whale is a mammal ...

Move for y

S: ...The silverfish is an insect.

T: Oh, we studied one and made a drawing of him.

Move for z

S: Crayfish

T: The crayfish. We talked about that a while ago...

(Smith et al, 1967, p.54).

In eliciting the names of animals (y, z) that have "fish" as part of their name, or that are usually referred to as fish (x) the teacher has accomplished the objective of explicating "biological misnomer" (d). These moves serve to bring out the meaning of the term (p.55).

Activities which introduce different kinds of information about a concept constitute different kinds of moves within a conceptual venture. Fifteen different kinds of moves, logically related to the teaching of concepts, have been identified by the authors (p. 62-82). In extending the author's initial work, Coombs reclassified and relabelled these fifteen moves in concept ventures into fourteen moves. For the purposes of this study Coombs' fourteen moves have been used and are presented for reference in the appendix.

Coombs (1969) describes the term epistemic rule as a set of conditions for appraising the correctness with which a specified teaching function has been performed in accomplishing the teaching of a concept. Coombs has derived two epistemic rules as guides in assessing the correctness of a teaching activity for concept teaching. These are given in the appendix.

Phase II: Characterizing A Record of Actual Teaching Strategies

There are two procedures in the characterization phase. The actual teaching strategies observed are classified into conceptual ventures. Classifications are performed in accordance with Smith and co-workers' (1967, Appendix 1) procedures and criteria. Then for each conceptual venture identified the moves of the venture are catalogued using the procedures and categories described in the appendix. In the second procedure possible information about the concept which has been introduced by the various moves is arranged with respect to the functions the moves might accomplish in teaching the concept.

Figure 2 contains a transcript of the segment of an actual lecture identified as a conceptual venture focused on the concept termed "Wave Superposition". The numbers in parenthesis in the margin next to parts of the transcript indicate moves identified in the venture. These are coded to the numbering scheme for moves shown in the Appendix.

Place Figure 2 About Here

Figure 2

Conceptual Venture Presenting the Term

"Wave Superposition"

Figure 2

A (5) This is a wave travelling but now let's find out how we could find about the wave length of this wave.

We could do it in the following way. We could have a wave travelling in one direction. The wave will be deflected at the other end--will travel backwards towards me; and the two waves, the one wave travelling in this direction and the other wave travelling backwards will then superimpose.

B (11) Let's do this, and the pattern I get with a frequency just looks like a wave, but it doesn't run. It's standing. So this is what we call a standing wave.

C (12) Let's do it again with a different frequency. Let's try to make another standing wave. I'll take a higher frequency-- (pause) --. This is a standing wave.

D (13) Now let's try to understand how these standing waves come about. To understand this we have the first--and essential principle. Have to remember...for most of you it's something you already did in school. We have to remember the principle of superposition of waves. So what we are setting out to do is, we are looking for experimental proofs of the wave nature of electromagnetic radiation--(pause) --.

E (1) And to do this we will make use of the principle of superposition. -- (pause) --. We could phrase it as follows. When two waves pass the same point at the same time the waves at this point always superimpose. Just let's write this down like this, and then we will discuss what it means. --(pause)--.

F (5) The meaning of this is as follows. Let's say we have one wave on this string. For instance, the wave I generated by moving my hand. And we have another travelling along the string. In this case the wave is travelling the other direction along this string. And this generated by reflection of the primary wave at the wall. Then, these two waves add up.

This means, for instance, if at this point we have a deflection upwards by the wave coming from this direction and upwards at the same time...by the way, from this direction we will get twice the amplitude, twice the deflection in this point.

G (5) Whereas, if the wave in this direction, for instance, upwards and the wave coming from the other direction would be downwards, then those two, if they have the same amplitude in this point, these two would cancel out. In this way the waves superimpose.

H (5) So to find the resultant wave pattern simply add up the wave pattern of the one wave and the wave pattern of the other wave and you get the resultant wave. Is this clear? That's called superimposed waves.

I (13) Now, I have to add a notice of caution for mechanical waves. This only holds for small amplitudes. When the amplitudes are large it doesn't hold any more. But with electromagnetic waves this always holds.

J (5) Now, let's try, on these grounds, to understand the standing waves we saw just now. Let's look at this primitive machine I've got here. This is simply a wire wound around another wire. And when I turn the crank here this looks like a wave moving. It's rather a shaky machine, but anyway it works. So this symbolizes a wave travelling toward the left. Now we have another wire of this kind and this wire is bent such that the wave is coming the other way. Now if we were going to superimpose those two waves, we would just be in the situation as we were with the rubber string. One wave travelling in one direction, the other wave travelling the other direction, and both waves being sine waves. So let's just look at the situation point by point, and let's see how these two waves are travelling along the same string. So the line, the intersection of the line with this wave are the same point on the string actually. We are superimposing those two waves. We have them side by side just to compare. And let's see what will happen. Now you will see that the wire in the centre between those just is bent that way, that it looks like a superposition of those two waves. At least it should.

K (13) Now you see at this moment the upper wave and the lower are just ending their amplitudes and therefore the result is a deflection of higher amplitude. Now, at this moment both of them are zero or almost counteracting. They are not quite properly bent I see. So they cancel out at this moment. Now both of them have negative amplitude. They add up that way that we have a negative deflection downwards. And so these two waves let's say here, for instance, then you will notice that the upper wave and the lower wave which are models for the wave travelling on the same string are always opposite, so they will cancel out. The upper wave is positive now, the lower wave is negative, cancelling. Both are zero. The upper is negative; the lower is positive; they are cancelling out. And therefore the superposition of those two waves in this point doesn't give a deflection all the time. Whereas the superposition of the waves in this point gives a maximum oscillation. And that is exactly what we saw when we saw the waves on the string. I produced a sine wave travelling the other direction. They superimpose in such a way that there are places of maximum oscillation and that there are places with no oscillation at all.

L (5) That's low frequency wave. We have one point which doesn't move at all. That's called a node. That doesn't move at all. Now let's take a higher frequency. It's still low frequency. Let's damp this down first. Now we have several nodes. Because I produced a sine wave travelling in direction towards the wall and the sine wave was travelling back and those two were superimposing.

Table 2 is a representation of the possible information about a concept which could be introduced through the various moves. Note first that the moves have been arranged with respect to the functions they might accomplish in teaching a concept. Column one of the Figure represents information providing theoretical or relational meaning for the concept; the second column represents information on experimental reference; and the third column represents information on the content within which the concept has application. Secondly, the moves have been organized into information categories according to the kind of information they provide about the concept. For example, below the information category termed "analogy", analogy and differentiation moves provide information of this type (move numbers 7 and 8 in the appendix).

Place Table 2 About Here

Also note that characteristic and case characterization moves may provide relational meaning and/or experiential reference. For instance, one could describe a watch by saying "one characteristic of a watch is that it is used to tell time." In this type of characteristic move the person has related the concept term "watch" to the concept term "time." Describing the watch by pointing out that "a watch has two hands which move on a face in accordance with the observed motion of the sun" is an example of a characteristic move providing experiential reference.

The actual information presented in the teaching strategy concerned with the concept termed "wave superposition" is presented in Table 3. The capital letters in the Table next to the short phrases are for cross-referencing with the lecture transcript in Figure 2. The parenthesized numbers are for reference in identifying the type of move as indicated in the Appendix.

Place Table 3 About Here

Reliability of the venture and move classifications performed by the writer established through a comparison of the writer's classification of actual teaching acts with that of an expert -- one of the major researchers of the conceptual framework used in the study, Professor J. Coombs.

TABLE 2. Representative Format for Information Presented in Concept Ventures

Concept: [ ]

Venture: [ ] Lecture Date: [ ]

FUNCTIONS TO BE ACCOMPLISHED IN TEACHING A CONCEPT*

Provide-theoretical or relational meaning	Provide-experential references	Provide-content
- force (6)		
Analogy	Subclass	Necessary and Sufficient Condition
- analogy (7)+	- subclass (4)	- sufficient condition ([illegible])
- differentiation (8)	- positive instance (11)	
- instance comparison (10)	- negative instance (12)	Appropriate Conte[illegible]
Classification	Characteristic	- [illegible] [illegible] ([illegible])
- classification (3)	- characteristic (1)	- use ([illegible])
Characteristic	- case characteristic (5)	- [illegible] ([illegible])
- characteristic (1)		
- case characteristic (5)		

* The teaching function accomplished by a particular move [illegible] some extent on the background information about the concept [illegible] by the student. To that extent the positioning of move categories in the table is an attempt by the writer to indicate which functions seem likely to be provided by the move categories. However, to determine the exact location of a move in the table empirical studies need to be performed.

+ The numbers in parenthesis refer to the type of move as described in the appendix.

Table 3. Potential Information about the Concept Termed "Wave Superposition" Venture 10.

Concept Term: "Wave Superposition"

Venture: 10 Lecture Date: March 3, 1970

FUNCTIONS TO BE ACCOMPLISHED IN TEACHING THE CONCEPT

Provide-theoretical or relational meaning	Provide-experiential reference	Provide-Context
	Subclass B - (11): Standing waves are example of wave superposition C - (11): This pointing to example is a standing wave.	
Characteristic E - (1): When two waves pass same point at same time always superimpose L - (5): Where waves superimpose there is point does not move called node.	Characteristic A - (5): Waves deflected back and returning along same path will superimpose with waves still on path. F - (5): Waves travelling opposite direction along same surface will add up when meeting. G - (5): Cancelling out is a type of adding up. H - (5): Resulting wave pattern when waves meet is addition wave pattern of one wave and that of another. J - (5): Combining amplitudes is means of adding up.	Context I - (13): For mechanical waves superposition only applies to small amplitude waves; applies for all electro-magnetic waves.

Phase III: Analysing and Evaluating Actual Teaching Strategies for Goodness-of-Fit with Ideal Teaching Strategies

An analysis of information introduced in a teaching strategy concerned with a concept yields "rules governing one's use of the concept term and one's behaviour with respect to including or excluding things from the class designated by the term" (Coombs, 1969, p.1). The rule-formulations (i.e., statement of the rule) are elicited from the information introduced by the moves in an actual conceptual venture. From the viewpoint of the conceptual framework the "intended product" of concept teaching is a complete set of rule-formulations for each concept taught.

The analysis procedure involves deducing rule-formulations which are the "potential product" of an actual teaching strategy, and deducing the rule-formulations constituting the "intended product." In the subsequent evaluation procedure the "intended product" is compared with the "potential product" and suggestions made for improving the match between them.

<u>Analysis Procedure Yielding A "Potential Product" From An Actual Teaching Strategy</u>. An epistemic rule has been formulated to serve as a guide for eliciting the rule-formulations of a concept from the information presented in actual teaching strategies. The epistemic rule is:

> The statement of each rule used in the description of a concept must be such that the rule accurately reflects the meaning and implications about the context of the concept term inferred from information in a venture.

The epistemic rule is used to determine if information presented by the instructor in a venture has been interpreted correctly in the analysis procedure. The test for correctness of interpretation is whether the description of a concept deduced from the venture is accurately displayed in the form of "a set of rules governing the use of the (concept) term" and "determining what things do or do not belong in a given class" (Definition of a Concept, Coombs, 1969, p.1).

As an illustration of the analysis procedure consider the following description of the concept called "Wave Superposition". Information presented in the form of moves in the venture concerned with "Wave Superposition" was characterized in Phase II into three categories according to "the function to be accomplished in teaching a concept": Providing relational meaning, providing experiential reference, and providing context. The displayed information, Table 3, is analysed by extracting key phrases or ideas which help to describe or define the concept.

For instance, the information "for mechanical waves superposition only applies to small amplitude waves; applies for all electro-magnetic waves" suggests ideas for formulating a rule to distinguish what things to do or do not belong to the class designated by the term "Wave Superposition." One formulation of the rule might be: "The class of things having the property 'Wave Superposition' should be limited to small-amplitude mechanical waves and all electro-magnetic waves." Another formulation of the same rule might be: "Mechanical waves other than those having small amplitudes are not to be placed in the class of things which have the property 'Wave Superposition' but the term applies to all electro-magnetic waves."

The epistemic rule is brought to bear on these rule-formulations by suggesting a further search for meanings and implications not already present in the rule, which could be inferred from the information given. Since the two rule-formulations stated above accurately reflect, as far as can be ascertained from the information given, the meaning and implications of the concept term "Wave Superposition" in the context given they constitute a "potential product" of at least this part of the venture.

An illustration of rule-formulations for the concepts termed "wave superpositions" is presented in Table 4. The first column indicates the concept term. The second column indicates the teaching function accomplished if the rule-formulation is the product of teaching the concept. The third column contains letters representing the section of the venture shown in Table 3 which formed the information used to deduce the rules for each concept taught. The letters represent the section of the venture from which information about the concept was abstracted, condensed, and presented in Table 3. The letters for this concept are also indicated next to sections of the actual transcript shown in Figure 2. The last column contains the rules formulated for the concepts as deduced from information contained in the ventures.

Insert Table 4 About Here

Analysis Procedure Yielding An "Intended Product" From An Ideal Teaching Strategy. The overarching content objective for a conceptual venture is the disclosing of conditions or criteria (rule-formulation) governing the use of the term (Smith et al, 1967, p.294). For a model conceptual venture (ideal teaching strategy concerning concepts), according to the conceptual framework, sufficient criteria or conditions must be disclosed to warrant the use of the concept term. The epistemic rules suggested by Coombs (1969, p. 1; also in Appendix) serve as a guide in developing criteria. Such a set of rule-formulations are the "intended product" of an ideal teaching strategy. In the form of rules governing the use of the term they are comparable to the rule-formulations resulting from an analysis of actual teaching strategies. In summary, then, this subsection presents a procedure which can be used to yield intended rule-formulations from ideal teaching strategies that fulfill the epistemic rules.

The theoretically possible information about a concept which could be introduced through moves in a conceptual venture has been displayed in Table 2. The kind of information each move can provide in teaching a concept is the starting point for proposing intended rule-formulations for the conceptual venture carried out by the instructor. Note, however, that the concern is with information at the level of abstraction identified in the course by the instructor i.e., suitable for first-year university physics students. Information for this purpose was obtained from first-year physics textbooks, the actual teaching strategies, statements by the instructor about his intended goals (i.e., the course rationale, the Pre-lecture Analysis Questionnaire), and other members of the Physics Faculty involved in similar undergraduate physics courses. The resulting information is then classified into moves and the moves characterized according to the teaching functions which could be accomplished in using them to teach the concept.

Table 4. The "Potential Product": Rule-Formulations for Actual Teaching Strategies

Concept Term	Function Provided in Teaching Concept	Coded Section of Venture	Rule Formulation
Wave Superposition	R.M.	A	(1) The term should be applied to the meeting of two waves travelling along the same path but in opposite directions.
	E.R.	E	(2) When two waves pass the same point at the same time the concept term applies.
	E.R.	F,G,H,J	(3) Adding the amplitude of two waves is called superposition of waves.
	E.R.	F,G,H,J	(4) When two waves superimpose they are in the class of things to which the term wave superposition may be applied.
	Cont.	I	(5) The term only applies to small amplitude mechanical waves but the term applies to all electromagnetic waves.
	R.M.	L	(6) If waves superimpose, at least one point along the wave will not move: This point is called a node.

The characterized information is used to formulate "rules governing the use of the term...". Each rule-formulation is checked for correctness by applying the epistemic rule described above (p.15). The set of rule-formulations obtained in this way is checked for completeness by applying the epistemic rules described in the appendix. The "intended product" then, is a set of rule-formulations or criteria sufficient to warrant appropriate use of the concept term.

As an illustration of the procedures the concept termed "Wave Superposition" has been selected. Table 3 presents information obtained from characterizing the actual teaching strategy for this concept. Rule-formulations deduced from the information are presented in Table 4. These rule-formulations constitute a possible subset of the ideal set of rule-formulations needed for the concept term. The ideal set are "intended product" of teaching the concept. Additional rule-formulations are now sought in order to have a set of criteria sufficient for using the concept term. We seek to formulate necessary or typical rules which are sufficient to allow application of the term in all situations to which it is typically applied in first-year university physics courses and rules which eliminate application of the term in all cases not appropriate to this school level.

For example, Orear (1967, p. 242) in a first-year university physics textbook indicates that when a single wave pulse is set in motion from one end of a taut string and simultaneously a single wave pulse is started at the other end, "the two pulses will cross through each other and continue to proceed in their own directions", unchanged in shape and velocity. The additional information is that the waves continue after crossing as if unaffected in the crossing event. Orear points to this occurence as the characteristic of "Wave Superposition" ("consequence of the Principle of Superposition", in Orear's terms, 1967, p.242). Since the information provides a characteristic feature of the concept that is potentially observable by students, the information could be characterized for teaching purposes, as providing experiential reference.

A rule-formulation deduced from the information could be: "Superposition of waves does not affect the initial form of the waves."

Another rule-formulation, for example, concerning wave superposition could be deduced from information supplied by Miller (1967) in another first-year university physics text. Miller specifies an important contextual limitation in applying the term "Wave Superposition". To use Miller's (1967, p.217) words, there is "a definite assumption about a medium when we involve the superposition principle of waves of some sort in a medium." An example of such an assumption is the idealization that for pulses on a coil spring: (1) the spring must be perfectly flexible; (2) it must have no internal resistance; and (3) it must be kept in a vacuum. In the actual teaching strategy the information concerning large amplitude mechanical waves does not seem to imply the same necessary rule-formulation. Not enough information was given about why the principle applies only to small amplitude mechanical waves. The rule-formulation deducible from combining Miller's information and that presented in Table 3 is: "The term wave superposition can be used in discussing all electromagnetic waves, and it can be used in discussing mechanical waves of small amplitude in which case deviations from ideal conditions of the medium are or can be considered to be negligible."

The epistemic rules in the conceptual framework are applied to the rule-formulations presented in Table 4 in combination with the two additional rule-formulations stated above by ascertaining whether the rules as formulated are necessary in order to warrant using the term "Wave Superposition". Examination of typical cases to which the term is applied in the two first-year university physics texts mentioned above, the transcript of the venture for the concept, reveals that the term is only applied to ideal cases -- idealized springs, strings, liquid surfaces -- and electromagnetic fields, and not to situations that oceanographers or engineers, for example, have to deal with. The rule-formulation given above allows application of the term "Wave Superposition" to typical cases and rules out application to atypical situations with significant deviations from idealized conditions such as waves along real springs, real strings held loosely, and real liquid surfaces. This rule-formulation, therefore, can be considered part of the "intended product" of the ideal teaching strategy for the concept called "Wave Superposition". The "intended product" for the ideal teaching strategy of each concept can be formulated by the same procedure.

In Table 5, column 1 contains the concept term; column 2 presents the source of the additional information; and column 3 contains a summary of the information needed in addition to that presented in Table 3. The rule formulated from the additional information, teaching function to be accomplished by using the information, and a tentative move category are presented in columns 4 to 6 of Table 5 respectively.

Insert Table 5 About Here

The rule-formulations given in Table 4 combined with those given in Table 5 represent the "intended product" of ideal teaching strategies for the concept described. The complete set of rule-formulations for the concept -- the "intended product" -- is presented in Table 6.

Insert Table 6 About Here

Evaluation Procedure. Matching rule-formulations of the "potential product" to rule-formulations of the "intended product" in order to identify missing, ambiguous, incomplete or redundant rules in the former, is the first step in the evaluation procedure. The second step is to specify a move or moves which should be performed in order to produce the missing rules. Choosing a move may be facilitated by considering the nature of the teaching function to be provided (i.e., Table 2). Finally, model moves are suggested which could be performed in order to meet the function proposed.

Again, the concept called "Wave Superposition" will be used to illustrate the steps in the procedure. Rule-formulations comprising the "potential product" and "intended product" are compared in Table 7. It is evident that rules 7 and 8 in the "intended product" are not present in the "potential product". However, rules 5 and 8 describe similar features of the concept (restrictions in applying the concept term to certain wave-types), but rule 5 is not as complete as rule 8.

Place Table 7 About Here

---

ble 5. **Rule-Formulations Derived from Information Other than Actual Teaching Strategies**

Concept Term (1)	Source of Information (2)	Additional Information (3)	Rule-Formulations (4)	Function in Teaching (5)	Move Category (6)
Wave Super-position	Orear, (1967 p. 242).	Two pulses cross through each other and continue to proceed in own direction unchanged in shape and velocity.	Superposition of waves does not affect the initial shape and velocity of the waves.	E.R.*	1 or 5
Wave Super-position (continued)	Miller, (1967, p. 217).	Important assumption about a medium are made when invoking the superposition principle for waves.	The term wave superposition can be used in discussing all electromagnetic waves, and it can be used in discussing mechanical waves of small amplitude in which deviations from ideal conditions of the medium are negligible.	Cont.	13

* These abbreviations are explained in Table 3

Refers to move categories described in **the appendix.**

Table 6. The "Intended Product"

Concept Name	Rule-Formulations
Wave Superposition	(1) The term should be applied to the meeting of two waves travelling along the same path but in opposite directions.
	(2) When two waves pass the same point at same time the concept term applies.
	(3) Adding up of two waves crossing is called superposition of waves.
	(4) When two waves superimpose they are in the class of things to which the term applies.
	(5) The term only applies to small amplitude mechanical waves but applies to all electromagnetic waves.
	(6) If waves superimpose at least one point along the wave will not move. That point is called a node.
	(7) Superposition of waves does not affect the initial shape and velocity of the waves.
	(8) The term wave superposition can be used in discussing all electromagnetic waves, and it can be used in discussing mechanical waves of small amplitude in which case deviations from ideal condition of the medium are negligible.

Table 7: Comparison of "Potential Product" and "Intended Product"

CONCEPT TERM: WAVE SUPERPOSITION

"POTENTIAL PRODUCT"	"INTENDED PRODUCT"
(1) The term should be applied to the meeting of two waves travelling along the same path but in opposite directions.	(1) The term should be applied to the meeting of two waves travelling along the same path but in opposite directions.
(2) When two waves pass the same point at same time the concept term applies.	(2) When two waves pass the same point at same time the concept term applies.
(3) Adding up of two waves crossing is called superposition of waves.	(3) Adding up of two waves crossing is called superposition of waves.
(4) When two waves superimpose they are in the class of things to which the term applies.	(4) When two waves superimpose they are in the class of things to which the term applies.
(5) The term only applies to small amplitude mechanical waves but applies to all electromagnetic waves.	(5) The term only applies to small amplitude mechanical waves but applies to all electromagnetic waves.
(6) If waves superimpose at least one point along the wave will not move. That point is called a node.	(6) If waves superimpose at least one point along the wave will not move. That point is called a node.
	(7) Superposition of waves does not affect the initial shape and velocity of the waves.
	(8) The term wave superposition can be used in discussing all electromagnetic waves, and it can be used in discussing mechanical waves of small amplitude in which case deviations from ideal condition of the medium are negligible.

Suggestions for Improving the Match Between Actual and Ideal Teaching Strategies. The next step is to specify particular moves based on empirical studies of teaching which when performed would present the information needed to deduce the missing rules. As the study was exploratory in nature empirical studies of preferred teaching strategies were not undertaken. Instead, teaching experience forms the basis of the move specifications. Suggestions for empirical studies are discussed in Phase IV of the methodology.

Table 5 contains suggestions for this evaluation step. Reading across the columns in the Table the information presented by Miller (column 3) can be translated into a rule-formulation (column 4) which could accomplish a function in teaching the concept (column 3) when presented as the proposed move category (column 6). The suggested move types can be used as a guide for suggesting new teaching activities which should be added to the actual teaching strategy; or, these move categories can be used as a guide for suggesting modifications to existing teaching activities which already had been classified as a particular move. Both suggestions could serve to improve the actual teaching strategies by bringing them more in line with the ideal.

The actual teaching strategy for "Wave Superposition" could be modified slightly in order to integrate into it the information needed to deduce the two additional rule-formulations. The information concerning wave independence (Table 6, column 3) could be integrated with section F of the actual lecture transcript (Figure 2). Since this section was catalogued as a case characterization move, a phrase indicating the independent nature of the crossing waves in the case cited would be sufficient. Another way of introducing the same information would be in the form of a characteristic move placed between coded sections E and F of the transcript. The move might be stated in the same words used in the rule-formulation. For the information concerning the nature of the medium, the "usage move" presenting information about mechanical and electromagnetic waves (Transcript section I, in Figure 2) might be expanded to include the information on medium. For example, the rule concerning transmitting medium could be deduced from the phrase: "A large amplitude wave would be one which permanently deformed the medium through which the wave travelled -- like -- shock waves breaking a crystal glass."

These modifications to the teaching strategy concerning "Wave Superposition" are only examples of possible ways of improving the match between actual and ideal teaching strategies. The specific teaching strategy proposed (including the suggested additions) should be logically sound and would require an experimental verification of the effectiveness of the strategy for meeting specified teaching goals. An instructor's task would involve determining which rule-formulation he can assume the students already have and which rule-formulations the students must deduce from information introduced in the teaching strategy. In this way, he could decide how to organize his teaching in order to maximize the clarity and precision of the "potential product."

Phase IV: Specific Problems Deserving Further Investigation

Three problems have been identified which deserve further investigation. The problems are viewed as ranging along a hypothetical continuum from theoretical at one end to practical at the other. In logical order, the problems begin with theoretical considerations and move toward practice. The problems identified are: a suggested expansion of the conceptual venture idea to include written material with other discourse when analysing a teaching strategy; devising teaching strategies for concept teaching by considering the "functions to be accomplished in teaching a concept" in terms of the "point-at-ability" of a concept; and a suggestion for employing the methodology as a tool in devising "A Handbook of Teaching Strategies for Selected Science Concepts." These problems describe a range of possibilities for further investigation arising from the work in this study. As an example of potential investigations consider one problem concerned with teaching concepts.

Nuthall in a study involving alternative strategies for teaching concepts and the resultant learnings, identified an important problem in concept teaching. Nuthall (1968) points out that it may be difficult to separate the teaching strategy from the kind of concept being taught. It may well be that each concept to be taught requires its own particular teaching strategy.

Analysing teaching strategies with respect to the denotative meaning of a concept (describing the physical features of a referent; Nunnally, 1967, p.540) was accomplished by Anderson (1968). Anderson described the denotative meaning of concepts in terms of the "ease-of-pointing" to features of the referent and the "number-of-pointings" necessary to describe the concept (i.e., point-at-ability of a concept; Anderson, 1968, p.60). Taking Anderson's approach to the problem of analysing the kinds of concepts to be taught and combining it with the approach taken in the present study -- as delineated in Table 3 -- may be one way of viewing the difficulty posed by Nuthall.

The following is an illustration of some of the possibilities in using the combined approach. Considering rule-formulations for the concept termed "Mass", as described by Bashook, 1971, one might still have difficulties in pointing to particular instances where the concept term "Mass" could be used. Yet, given an instance, one could say whether the term "Mass" was used properly in the instance or not. The distinguishing feature between the two situations is that for the first situation one is asked to "point-at" an instance, while in the second situation an instance is "pointed-out" and one must indicate whether the term "Mass" applies or not.

Now, if the same two situations are considered for the concept termed "Wave Superposition" it would appear more likely that the rule-formulations for this concept (Table 6) are adequate for one to apply the concept term correctly in both situations. The difference between the concepts in these two situations lies in their "point-at-ability" -- the concept termed "Wave Superposition" seems easier to "point-at" than the concept termed "Mass."

The teaching strategies employed differ for each concept. Table 8 summarizes the types of moves actually employed for each. Note that approximately the same number of moves were involved for the concepts when the teaching functions were to "provide relational meaning" or "experiential reference", and that more than twice the number of moves were used in providing content for the concept termed "Mass" when compared with "Wave Superposition." Keeping in mind the "point-at-ability of the two concepts, "Mass" being more difficult to "point-at" than Wave Superposition", the different functions to be accomplished in teaching these concepts should be considered. For example, it may be advisable to provide additional content in teaching concepts difficult to "point-at" (less "point-at-able") such as "Mass" than to more "point-at-able" concepts such as "Wave Superposition". It is suggested that fruitful investigations into the problem of devising teaching strategies for concept teaching may be developed by considering the "functions to be accomplished in teaching a concept" in terms of the "point-at-ability" of a concept.

Place Table 8 About Here

Summary and Conclusions

This study has explored the possibility of devising a method, based on a conceptual framework of teaching developed by Smith and co-workers (1962, 1967; Coombs, 1971), which could be used to analyse and evaluate the teaching strategies employed in science courses to teach science concepts. The goal of the study has been to prepare a method to bridge the gap between theoretical knowledge of teaching and practical problems in science teaching.

The methodology developed in the study, was illustrated by applying it to actual teaching strategies used to teach concepts in a first-year university physics course. The methodology requires four phases: Identifying aspects of the conceptual framework potentially useful for analysing and evaluating the teaching of science concepts; characterizing records of actual teaching strategies; analysing and evaluating actual teaching strategies for goodness-of-fit with ideal teaching strategies; and suggesting specific problems arising from the study requiring further investigation. Illustrations of each phase were presented and discussed.

Unique contributions in the methodological bridge include: procedures in Phase II for organizing the information presented as moves in a conceptual venture with respect to the functions they accomplish in teaching a concept; and displaying the organized information in summary form (Table 2). The four procedures in Phase III resulting in a means for comparing ideal and actual teaching strategies are: deducing rule-formulations for a concept seen as the "potential product" of an actual teaching strategy; deducing an ideal

TABLE 8. Record Of Moves Used In Actual Teaching Strategies

Concept Term	Provide Relational Meaning (Move Number)* 1	3	5	7	8	10	Total Moves	Provide Experiential Reference (Move Number)* 1	4	5	11	12	Total Moves	Provide Content (Move Number)* 2	6	9	13	14	Total Moves
Mass		2		1			3	2		5			7			4	1	2	7
Law in Physics	2		1		3		6	5		2	1		8		1			1	2
Electricity		2		1			3	1	2	3	1		7						--
Electric Field					2		2	1		3			4			3			3
Number of Field Lines							--			2			2			2			2
Feedback			1				1		1	2			3					2	2
Wave Superposition	1		1				2			5	2		7				3		3
Nuclear Binding Energy		1					1			3	1		4				2		2
Total . . .	3	5	3	2	5	--	18	9	3	25	5	--	42	--	1	9	18	3	21

*As described in the appendix.

set of rule-formulations as the "intended product" of an ideal teaching strategy for the same concept; evaluating the match between the "intended product" and "potential product" for similarity of information; and proposing alternatives or additions to the actual teaching strategy in the form of moves which could bring it more in line with the ideal. In Phase IV, three specific problems arising out of the development of the methodology and encouraging sources of further investigation were identified and described. The problems were envisioned as being along a hypothetical continuum from theoretical problems at one end, to practical problems at the other. The theoretical problems had to do with specific difficulties in using the "conceptual venture" categorizations. At a somewhat less theoretical place in the continuum, specific problems were raised concerning concept teaching. At the practical end of the spectrum a problem of classroom practice was identified and a tentative solution suggested in the form of a "Handbook of Teaching Strategies for Selected Science Concepts."

A general conclusion of the study is that the theoretical framework used appears to be potentially useful for analysing and evaluating certain aspects of classroom teaching. The venture and move categorizations of the framework proved tractable for analysing actual teaching strategies performed in a lecture-type teaching situation.

It should be emphasized that identifying the "intended product" of a teaching strategy is most difficult. If the methodology is employed by a teacher, then his personal determination of what he hopes to be the information presented in teaching would be the source for deducing rule-formulations representing the "intended product". On the other hand, if a person external to the teaching (i.e., an evaluator of the course or curriculum designer) were to employ the methodology some clear statement of the necessary and sufficient rule-formulations needed to understand the concept would be required as the "intended product." The rules might be obtained by requesting a group of experts in the subject matter area to indicate what information must be presented, in a teaching strategy or available to the students, for the students at a given level of schooling to understand the concept.

Classifying and organizing the information introduced by the various moves of a venture in terms of the functions to be accomplished in teaching a concept, appears useful not only for deducing rule-formulations for the concept embodied in a teaching venture, but also for evaluation purposes by identifying which function probably was not accomplished because appropriate moves were not made, or because the moves made were defective in some way.

Tabulations of the information introduced about a concept in the form of moves made in accomplishing the teaching functions can also be used to suggest teaching strategies that may, on logical grounds, be more effective than others. It was pointed out in the study, that concepts appear to differ in "point-at-ability" and that it may be advisable to consider devising teaching strategies with this aspect of concept teaching in mind. In addition, in cases for example, where the concepts are hard to define because of difficulty in accomplishing the "experiential reference" function, it is suggested that additional moves providing "relational meaning" and "contextual information", be included in the teaching strategy to be devised. Although the methodology developed does not suggest a "best" strategy for any particular concept, a problem for experimental study, it does suggest at least some consideration for devising teaching strategies for a concept.

The results of analysing conceptual ventures as demonstrated in the study are seen as potentially useful information to the teacher. In particular, a display of the rule-formulations for a concept deduced by this procedure, constituting both the "potential product" and the "intended product" of concept teaching, is seen as a useful check for the instructor on how congruent his teaching was with his intents. Information about congruency of intents with teaching acts may suggest additional actions which need to be taken for improving teaching performance and identifying possible sources of difficulty students may be having in learning a concept. Further experimental study is needed to determine what the effects are on student learning of different kinds of teaching strategies and the degree of accomplishment of the functions of a particular teaching strategy.

Although the methodology developed was only applied to concept teaching, it would appear to be generalizable to other kinds of teaching as well. For example, in science teaching there is considerable concern with causal ventures in which cause-effect relations are taught. Concept and causal ventures, along with six other common classroom teaching ventures are provided for in the conceptual framework used in the study and should therefore make the methodology applicable in these teaching situations.

Finally, it should be recognized that the study is limited to being exploratory in nature. It is intended that it provide an empirical base for subsequent experimental studies in teaching and that an instructor familiar with the methodology presented could use it in attempting to evaluate his own concept teaching. The methodology is seen as providing a possible way of linking an important theoretical view of teaching to classroom practice and, in so doing, provide a basis for future experimental investigation.

Literature Cited

Anderson, Eugene. 1968. "An Exploratory Study of the Relationship Between Kinds of Concepts and Teaching Strategies (Unpublished Doctoral Dissertation, Urbana, Illinois: University of Illinois).

Bashook, Philip G. 1971. "Developing a Methodology for Analysing and Evaluating Teaching Strategies in University Science Teaching: An Exploratory Study" (Unpublished Doctoral Dissertation, Vancouver, British Columbia: University of British Columbia).

Bellack, Arno A., Herbert M. Kliebard, Robert T. Hyman, and Frank L. Smith,Jr. 1966. The Language of the Classroom. New York: Teachers College Press, Columbia University.

Bleger, T.C., and R.M. Cooper, (editors). 1950. The Preparation of Teachers. Washington, D.C.: American Council of Education. p.123.

Broudy, Harry S. 1965. "Criteria for the Professional Preparation of Teachers". Journal of Teacher Education. 16 (4), 408-415.

Coombs, Jerrold. 1969. "Teaching Concepts" (Vancouver, British Columbia: Faculty of Education, University of British Columbia, mimeographed).

Easley, John A.,Jr. 1967. "Logic and Heuristic in Mathematics Curriculum Reform." Problems in the Philosophy of Mathematics. edited by Imre Lakatos. Amsterdam: North-Holland Publishers, pp. 208-241.

Faculty of Science Calendar, 1969-1970, University of British Columbia. Vancouver, British Columbia: University of British Columbia.

Flanders, Ned A. 1970. Analysing Teaching Behaviour. Don Mills, Ontario: Addison-Wesley.

Gage, N.L.(editor). 1963. Handbook of Research on Teaching. Chicago: Rand McNally.

Green, Thomas F. 1968. "A Topology of the Teaching Concept". Concepts of Teaching: Philosophical Essays. edited by C.J.B. MacMillan, and Thomas W. Nelson. Chicago: Rand McNally. pp. 28-62.

Henderson, Kenneth B. 1967. "A Model for Teaching Mathematical Concepts." The Mathematics Teacher. 60, 513-577.

Hyman, Ronald T. (editor). 1968. Teaching: Vantage Points For Study. New York: Lippincott.

Kuhn, Thomas S. 1962. The Structure of Scientific Revolutions. Chicago: University of Chicago Press.

Kuhn, Thomas S. 1963. "The Essential Tension: Tradition and Innovation in Scientific Research." Scientific Creativity: Its Recognition and Development. edited by Calvin W. Taylor and Frank Barron. New York: John Wiley & Sons. pp. 341-354.

Miller, Franklin Jr. 1967. College Physics. Second edition. New York: Harcourt, Brace and World.

Nunnally, Jim C. 1967. Psychometric Theory. Toronto: McGraw-Hill.

Nuthall, Graham. 1968. "An Experimental Comparison of Alternate Strategies for Teaching Concepts." American Educational Research Journal. 5 (4), 561-584.

Orear, Jay. 1967. Fundamental Physics. Second edition. New York: John Wiley & Sons.

Perlberg, A., and D.C. O'Bryant. 1968. "The Use of Video Tape Recording and Micro-Teaching Techniques to Improve Instruction on the Higher Education Level." (Urbana, Illinois: Department of General Engineering,College of Engineering, University of Illinois, mimeographed).

Physical Science Study Committee. 1965. Physics, Second edition. Toronto: Heath. pp. 327-328.

Physics Education Evaluation Project. 1970. "Evaluation of Physics Teaching at the First Year University Level: An Interim Report, January 1970." (Vancouver, British Columbia: University of British Columbia, mimeographed).

Roll, Peter G. 1968. "Introductory Physics Textbooks." Physics Today. 21 (1), 63-71.

Ryan, T.A. 1969. "Research: Guide for Teaching Improvement." Improving College and University Teaching. 12 (4), 270-276.

Smith, B.O. 1961. "A Concept of Teaching". Language and Concepts in Education. edited by B.O. Smith and Robert Ennis. Chicago: Rand-McNally. pp. 86-101.

Smith, B.O., M. Meux, et al. 1962. "A Study of the Logic of Teaching" (Urbana, Illinois: Bureau of Educational Research, University of Illinois, mimeographed).

Smith, B.O., Milton Meux, Jerrold Coombs, Graham Nuthall, and Richard Presians. 1967. "A Study of the Strategies of Teaching" (Urbana, Illinois: Bureau of Educational Research, University of Illinois, mimeographed).

A P P E N D I X

Epistemic Rules for Analysing Conceptual Ventures

The moves in a conceptual venture should lead to explicating the concept under discussion. Coombs suggests two epistemic rules for analysing a venture. These are:

1) The discussion must adduce a set of criteria (necessary or typical conditions) which are sufficient to warrant the use of the concept term. We check to see if we have a set of sufficient criteria by determining whether the criteria allows application of the term in all cases we ordinarily apply it, and rules out its application in all cases we ordinarily don't apply it. If it is a technical term its use by the specialist in the technical areas rather than its use by ordinary careful language users is the point of reference.

2) Within reasonable limits the more sets of sufficient conditions adduced the better. Sufficient conditions provide recognition power. The greater the number of sufficient conditions one knows the greater the chances he will be able to recognize cases in which the concept applies.

(Coombs, 1969, p.1)

Catalogue of Moves Relevant to Teaching Concepts

In conceptual ventures the concern is with the presentation of information for the explication of the concept. Smith and co-workers have identified four major concerns of teachers when explicating a concept:

1) Presenting information which results in students being able to describe the concept (descriptive moves);

2) Identifying differences between the concept and some other concept (comparative moves);

3) The direct description of characteristics or qualities of the concept through a discussion of instances (instantial moves).

4) The use of the concept in reading or learning about more advanced subject matter (<u>usage moves</u>).

Below are descriptions and example moves in each of the four categories.

Descriptive Moves

1. <u>Characteristic</u>

The referent is described as having a particular characteristic or feature. Example -- concept being taught <u>cerebrum</u>:

T: What is the form of the cerebrum?

S: Spheres.

T: Hemispheres. In other words it is divided into two parts and we call them hemispheres.

2. <u>Sufficient condition</u>

It is pointed out that a given feature or set of features is sufficient to identify something as an instance of the reference class. Example -- concept being taught <u>acid</u>:

T: Now, if you were asked to identify an acid, could you?

S: It has ionizable hydrogen.

3. <u>Classification</u>

The reference class of the concept is identified as a subclass of some more inclusive class of things. Example -- concept being taught <u>habit</u>:

T: How would you define habit?

S: It's an acquired reflex.

4. <u>Subclass</u>

It is pointed out that a given class of things is a subclass of the reference class of the concept. Example -- concept being taught <u>crime</u>:

T: Is a felony one type of crime?

S: Yes.

5. Case Characterization

A case is described and the concept term is used to make a significant statement characterizing the case. Example -- concept being taught socialization:

T: Can anyone tell me what socialization means?

S: When a kid plays with a group of kids and he starts to think like them, to like what they like and that sort of thing, he's being socialized.

T: Yes, socialization of the child is taking place in that case, isn't it?

6. Force

It is pointed out that the concept name has a given emotive, persuasive or evaluative force. Example -- concept being taught propaganda:

S: Doesn't propaganda mean something bad?

T: Yes, we generally think of propaganda as something bad.

Comparative Moves

7. Analogy

The way in which the referent is similar to the referent of some other concept is pointed out. Example -- concept being taught nervous system:

T: What would the nervous system correspond to in a building?

S: The system of electrical wiring.

8. Differentiation

The way in which the referent differs from the referent of some other concept is pointed out here. Example -- concept being taught parole:

T: What's the difference between probation and parole?

S: Parole -- you have to serve part of a prison sentence. Probation -- you don't, but you still have to report practically every week.

9. Contextual Definition

It is pointed out that a given expression employing the concept name is equivalent to another expression. Example -- concept being taught pluralism:

T: Can you tell me what pluralism means?

S: Well, a pluralistic society is -- is a society made up of people with lots of different points of view.

10. Instance Comparison

The similarities or differences between two or more things described as instances of the concept are pointed out. (sub-class comparison) Example -- concept being taught amphibia:

T: Where else do we have a big difference in these animals?

S: The salamander still has its gills but the frog lost its gills from the tadpole stage into the adult stage.

Instantial Moves

11. Positive Instance

Some object, event or condition is described or pointed out and is identified as an instance of the concept (member of the reference class). Example -- concept being taught satire:

> T: This book we're reading is one of the finest examples of a novel that is satire.

12. Negative Instance

Something similar to but not an instance of the concept is described or pointed out and identified as not being an instance of the concept. Example -- concept being taught voluntary act:

> S: When something flies at my eyes and I blink, this would be a voluntary act, wouldn't it?
>
> T: No, I don't think so.

Usage Moves

13. Use

The concept name is correctly used in the context of a sentence or a larger utterance. Example -- concept being taught scarcity:

> S: It's because of scarcity that we have to make priorities to how we're going to spend the country's money.

14. Meta-distinction

The nature of a concept, the different meanings a term can have, etc., are described or pointed out. Example -- concept being taught imperialism:

> T: Some terms like imperialism have more than one kind of meaning. They tell what something is, but they also tell how we feel about it.

(Coombs, 1969, pp. 14-15)